

| 8 |

Raw Materials

The approach of this book to its subject matter is longitudinal; that is we try to look down the length of the brewing process to detect how beer properties arise and how, at multiple stages, the outcome of the process is affected. The book could have therefore been written with but two chapters entitled (a) Raw Materials and (b) Processes. Much of what we might want to say about raw materials, however, is subsumed in other chapters, e.g., Modification, Color, Enzymes and pH, to satisfy the structural plan of the book. There is intentionally therefore not a great deal of material left over for a long chapter on raw materials. The main motivation for including such a chapter at all is that we have made relatively little mention of hops and that is curious, if not fatal, in a brewing text; that is where we begin this chapter.

HOPS

Hops are added in brewing in either or both of two places: in the kettle and/or after fermentation. The objective is the same in each case: to make beer bitter to an exact, consistent and repeatable level. Over the lifetime of most senior brewers in the industry, no raw material has evolved and improved more than hop products. The starting place for hop products

Assessing Resins in Hops

In the United States, hop α -acids are measured spectrophotometrically. They are extracted with toluene and the absorbance of the extract after dilution in methanol is assessed at 275, 325 and 355 nm.

$$\alpha\text{-acid}(\%) = d (-51.56A_{355} + 73.79A_{325} - 19.07A_{275})$$

where d is a dilution factor (typically 0.667).

As hops age and deteriorate the ratio of A_{275} to A_{325} increases.

In some locations, α -acids are assessed from a titration with lead acetate and monitoring of electrical conductivity. As increasing quantities of lead acetate are added, there is a decrease in conductivity up to the point at which there is an equivalence in concentration of the positively charged lead and negatively charged hop resins, after which the conductivity increases again. The more lead acetate needed to reach the “low point,” the more resin in the hops.

is where it has always been—in the hop yards of Germany and Europe generally and some western states of the USA; there are increasing and improving supplies from China and Australasia. Hops are prized eponymously as aroma hops or bittering hops. Their uncompromised quality is important to brewers. Beyond such expected analyses as moisture, bittering potential (α -acid content) and the hop storage index (A_{275}/A_{325}), brewers are concerned with contaminants, especially pesticide residues. Dried compressed whole hops or hop cones (sometimes incorrectly called “leaf” hops or hop “flowers”) are then converted to a range of hop products, such as pellets or extracts, that are more stable to oxidation, more compact, more easily transported and stored, more standardized (e.g., in terms of α -acid content and blend of varieties), easier to quantify and easier to use in practice; e.g., with automatic addition and with less (or zero) waste that is more easily handled, and some extracts that are insensitive to light. As a result, in the long run, these products are more cost effective than whole hops, and most beers these days are made with some form of hop pellet or hop extract or combination of the two.

Hops add bitterness to beer and this is a primary reason for using them, as beer without any bitterness is bland and satiating. Nevertheless, bitterness

is not a quality most consumers like and so hop bitterness must be artfully melded with the other qualities of the beer. Commonly, therefore, there is a good correlation between the overall flavor impact of a beer derived from malt and yeast and its analytical bitterness; however, beer pH also affects the perception of bitterness because it affects the dissociation of the iso- α -acids present. Lower pH generally yields finer but less intense bitterness as the α -acids associate. For the same reason, lower beer pH also increases the antimicrobial properties of iso- α -acids, provided they are present in sufficient amount. Hop compounds also help to stabilize beer foam, which, in the case of compounds like tetra-hydro-iso- α -acid, is a particularly notable and characteristic quality. Iso- α -acids are hydrophobic and tend to separate onto surfaces of all kinds, e.g., vessels, trub, yeast; this accounts substantially for the relatively poor utilization of α -acids added to the kettle. Iso- α -acids migrate into foam bubbles where they might well form complexes with, e.g., proteins that are detergent like, surface active and hence foam stabilizing. Beer foam is always more bitter than the beer from which it came.

α -acids of hops are insoluble in beer and so for all practical purposes they are not bittering. When heated near boiling, however, they melt and isomerize (change their molecular shape) to iso- α -acids, and in a vigorous “full rolling” boil these are reasonably soluble in wort and persist into beer. A full rolling kettle boil is also necessary for wort sterilization (see Chapter 6) and precipitation of some unwanted protein (see Chapters 4 and 5). Higher wort pH and the presence of ions, especially Ca^{++} , accelerates isomerization reactions and doubtless promote higher utilization of hop α -acid; however, desirable *quality* of bitter flavor and wort color are compromised at higher pH and hot break is reduced. This might not be of particular concern for dark beers and stouts but is undesirable in pale and delicate ones. Utilization (%) of hop substances in the wort kettle is reduced by high wort gravity, especially in all-malt worts, and by high hopping rates; generally, utilization is affected by the tendency of iso- α -acids to attach to surfaces of vessels (hence small vessels reduce utilization) and to “break” or “trub” particles, to finings and filter aids and to yeast cells and fob during fermentation. Thus, the kettle efficiency is only a part of the overall efficiency of hop utilization.

The need to improve hop utilization (from, e.g., 40% to 85%) has driven a significant move to postfermentation hopping, using isomerized hop extracts of various kinds. These days, they are made mainly from hop α -acids extracted with CO_2 and then treated with divalent metal ions (usually Mg^{2+}) under slightly alkaline conditions. This technology has also permitted light-stable hop extracts to be produced by reduction of the susceptible double bond of the iso- α -acid molecule; this prevents the formation of 3-methyl-2-but-1-ene thiol (iso pentenyl mercaptan) that has the aroma of skunks.

Hop Utilization

Hop utilization is an expression that quantifies the extent to which the resins available in hops and hop products manifest themselves as bitterness in beer:

$$\text{Hop utilization(\%)} = \frac{\text{iso-}\alpha\text{-acids in beer} \times 100}{\alpha\text{-acids introduced}}$$

For cone hops the value is usually rather low, e.g., 25% to 30%. The brewer will therefore need to add proportionately more hops to the kettle to account for the poor efficiency of conversion. Pellets and extracts added to the kettle will afford better utilization, but naturally the best values are obtained when isomerized extracts are added to the finished see and there is the least opportunity for the relatively insoluble molecules to be lost by adhesion to yeast and other particles. Note that in the strictest sense of the term, utilization for a isomerized material involves comparison of iso- α -acids remaining in beer with iso- α -acids, rather than α -acids added. Another key advantage is that the use of such materials means that less undesirable material is added. If, for example, a cone of whole hop addition was made from a hop of relatively low α -acid content with poor utilization, then to achieve the desired bitterness in a product of significant BU value would mean that considerable vegetable matter would have to be added to the kettle. Within that material would be substances such as polyphenols that may be undesirable, e.g., from a colloidal stability perspective.

BARLEY

Barley, almost always in the form of malt, provides the bulk of the extract for most worts, and is an essential source of nonsugar nutrition for yeast comprising amino acids, vitamins and minerals. For making malt, barley must be of a suitable malting variety, sufficiently low in protein (11%–13% as N $\times$ 6.25), adequately free of dockage and skinned and broken materials, highly viable (at least 96%) and quite low in moisture (12%–14%), and the lot should have a high proportion of plump grains. Ideally, the endosperm should be “mealy” (i.e., paper-white and opaque and containing a myriad of

Hop Products

Product	Nature	Stage of addition
Leaf hops	Whole hop cones	Kettle
Pellets	Cones hammer-milled, blended to desired mix, extruded	Kettle
Isomerized pellets	As for pellets, but isomerization agent added to powder and pellets held warm to promote isomerization	Kettle
Hop extracts	Liquid carbon dioxide extraction of powdered hops	Kettle
Isomerized kettle extract	As for hop extract, but extract isomerized	Kettle
Isomerized extract	Hop extract fractionated into resin and oil components and resin isomerized	Beer
Reduced isomerized extract	Isomerized extract with addition of two (rho), four (tetra) or six (hexa) hydrogen atoms to afford increased light resistance	Beer
Aroma extract	Hop extract fractionated to remove resin component	Beer
Late hop extract	Aroma component from extract separated into spicy and floral components	Beer

air-cells throughout the endosperm) not “steely” (i.e., somewhat grayish and translucent—a condition promoted by high protein, poor growth conditions and inadequate storage). Mealy grains take up water more rapidly and evenly during steeping.

Barley is harvested in the fall (in the northern hemisphere), but is malted all year and so must be stored. Successful storage depends upon grain temperature, moisture content of the kernels and time as well as conditions like the purity and cleanliness of the lot and absence of broken grains. The enemies of barley in storage are microbes, insects and grain respiration and neither dryness nor coolness protects them from all the enemies; the grain must be stored cool *and* dry, e.g., a rule-of-thumb “13/13,” that is no more than 13°C and 13% moisture. The grain must be moved and cleaned on a regular basis. Prolonged dry storage permits the grain to pass

through dormancy and water sensitivity (most easily construed as residual dormancy) until it is ready for malting. The last of a season's crop is usually malted some 15 months or so after harvest, and this is a typical target storage period.

After the barley is selected, stored, separated (to remove unwanted grains and broken kernels) and graded (to select kernels of the same size), it is brought to the barley washer and thence to the steep tank that initiates the malting process; the grain takes up water and swells and life processes resume. Respiration (an oxygen consuming process) rises and throughout the steeping process maltsters provide adequate aeration to prevent stifling of the grain. Over about 48 hours, the moisture content of barley rises from about 12% to a target moisture content in the range 42% to 48% depending on the maltster's objective and the characteristics of the barley. Generally, high steep-out moisture is used to make colored malt or to achieve high modification (at the cost of high malting loss) or if the barley is slow to germinate for some reason. Pale malt is generally made from vigorous barley, and the steep-out moisture is therefore at the low end of the range. If gibberellic acid (GA_3 , with or without bromate) is used to promote germination, it is usually added to the final steep water or to barley en route to the germination vessel. The level used is about 1 mg/kg of dry barley.

After steeping, barley is drained and moved to a germination vessel that is designed to make it easy to control the conditions under which the barley germinates. This in turn controls the modification of the barley endosperm, i.e., the sum of changes that barley undergoes as it is transformed from barley to malt. These changes are so important and far reaching that we devote a separate chapter to modification and its effects in brewing (see Chapter 9). Germination takes about four days, during which time the temperature of the grain bed rises from about 15°C to about 20°C, despite (1) constant application of a stream of cool humid air throughout the period of germination and (2) regular turning of the grain to promote even air flow and prevent entanglement of rootlets. As the grains grows during germination, it breaks down its own storage substance (the endosperm materials) to provide energy and matter for embryo growth; this causes heating up of the grain bed and malting loss, i.e., the loss of dry substance as CO_2 and H_2O are formed during ATP generation. Available extract is additionally lost as rootlet (counted as part of the malting loss) and shoot. During germination, barley is capable of producing from the aleurone layer and scutellum, a sufficient spectrum of enzymes to reduce the endosperm substance entirely to its basic building blocks—e.g., primarily sugars and amino acids—and given time could consume them entirely to build the substance of a new plant. This occurs in the field but is assiduously avoided by the maltster who curtails germination at the most opportune moment

Enzyme action in malting and brewing

Process Stage	Treatments	Events	Endogenous Enzymology	Exogenous Enzymology
Raw barley	Storage—perhaps to break dormancy	Hormonal changes—ill-defined	Few enzymes in raw barley: Main ones carboxypeptidase and bound, inactive β -amylase	
Steeping	Water added, interspersed by air rests, to raise water content of embryo and endosperm; up to 48h at 14–18°C	Synthesis of hormones by embryo, hydration of 'substrate' (starchy endosperm)	No apparent increases reported	
Germination	Controlled sprouting ('modification') of grain—typically 4–5 days at 16–20 °C	Synthesis of enzymes by aleurone and migration into starchy endosperm; sequential degradation of cell walls, some protein, small starch granules and pitting of large granules	Solubilization of β -glucan by solubilases (?) and endo- β -glucanase; degradation of arabinoxylans by arabinofuranosidase and endo-xylanase; partial hydrolysis of proteins by endo-peptidases and carboxypeptidase; development and limited action of α -amylase; splitting of β -amylase from protein Z; synthesis of bound and free limit dextrinase, and activation of latter	Microbial flora may contribute enzymes; opportunities for use of selected starter cultures?

Process Stage	Treatments	Events	Endogenous Enzymology	Exogenous Enzymology
Kilning	Heating of grain through increasing temperature regime (50–220°C) for desired properties: enzyme survival, removal of moisture for stabilization, removal of 'raw' flavors, development of 'malty' flavors and color	Enzyme survival greater with low temperature start to kilning and lower final 'curing' temperature. Increased heating of malts of increased modification (i.e. higher sugar and amino acid levels) gives increasingly complex flavors and colors via Maillard reactions	Some continued action of all enzymes at lower onset temperatures; but then solely an enzyme inactivation issue. Lability of enzymes endo-β-glucanase, limit dextrinase, lipoxigenase> endo-peptidase> β-amylase, lipase> solubilase > α-amylase, peroxidase Lipoxigenase may catalyze this reaction (c.f. enhancement of bread-making by analogous reaction in wheat protein); lipoxigenase decays during malt storage	
Malt storage	3–4 weeks ambient storage, otherwise wort separation problems later	Unknown, but may relate to development of cross-links between proteins through oxidation in mashed of unstored malt		
Mashing	Extraction of milled malt at temperatures between 40 and 75°C	Enzymolysis continued; gelatinization of starch at >62°C	Continued β-glucanolysis favored at low temperatures—also possibly further proteolysis; starch degradation greatly facilitated by gelatinization; balance of enzymes acting faster at higher temperatures with increased destruction of more sensitive ones	Use of heat-stable β-glucanase from <i>Bacillus</i> or fungi comprises main use of exogenous enzymes in high malt mashes; use of glucoamylase to promote fermentability (Light beers)
Use of adjuncts	Solid adjuncts used in brewhouse, taking advantage of malt enzymes (liquid sugars are products of acid and enzyme action in sugar factory and added at boiling stage)	Cereals with higher starch gelatinization temperatures than for barley need pre-cooking before combining with main mash	Ditto—also a degree of dilution of malt enzymes; especially with high adjunct use	Use of highly heat-resistant α-amylase to promote gelatinization in cooker; Use of amylase, protease, β-glucanase mixtures in main mash

Boiling	1–2h at 100°C, before cooling	To sterilize, extract hops, concentrate, and kill all residual enzymes	No enzymology	
Fermentation	Wort pitched with yeast and fermented for 3–14 days at 6–25°C	Fermentation of glucose, maltose, sucrose, maltotriose to alcohol; enzymic production of various flavor compounds (alcohols, esters, fatty acids, sulfur-containing compounds etc) Synthesis and removal of diacetyl as an offshoot of amino acid production	Emden-Meyerhof-Parnas pathway and offshoots	Addition of acetolactate decarboxylase to convert acetolactate precursor to acetoin, thereby circumventing 'natural' route which is non-enzymic breakdown of acetolactate to diacetyl (butterscotch), which is slowly reduced by yeast enzymes to less flavor-active acetoin
Cold conditioning and filtration	–1°C for ≥ 3 days; then filtration	Precipitation, sedimentation and removal of solids	Slow action by any enzymes 'leaked' from yeast, e.g. proteinases: detrimental to foam	Filtration can be limited by viscous polysaccharides, ergo advantage of using β-glucanase in brewhouse (or fermenter). Some use papain as a haze-preventative—but risk of removing foam polypeptides
Package	Market-driven	Progressive deterioration by chemical reactions, including oxidation	Unpasteurized, 'sterile-filtered' beer; may retain some of these enzymes	Use of glucose oxidase/catalase as an oxygen scavenger has been suggested

for malt quality by achieving sufficient modification with minimum malting loss.

Enzymes are proteins (see Chapter 10) and therefore are prone to denaturation by heat. During kilning of malt profligate enzyme destruction does occur and the enzymic quality of dry malt is a shadow of the green malt from which it is made, both in terms of the *amount* and *kinds* of enzymes present; only these surviving enzymes are carried forward into mashing in the brewery. Although traces of many enzymes might survive kilning, brewers evaluate malt on the presence of only the starch-digesting amylases: they measure DP or diastatic power (also DU or dextrining units) (see Chapters 9 and 10). From the point of view of wort quality, it is best to assume that the primary action of enzymes, other than amylases, is confined to the malting process and that their action in mashing is minimal.

During the final drying and toasting (curing) stage of malt kilning, some enzymes survive because they are intrinsically stable and can tolerate heat in a dry environment. In this stage also, the characteristic color and flavor of malt is generated primarily through a complex interaction

Flavor Descriptors for Malt Character

<i>Note</i>	<i>Thesaurus</i>
Cereal	Cookie, biscuit, hay, muesli, pastry
Sweet	Honey
Burnt	Toast, roast
Nutty (green)	Bean sprout, cauliflower, grassy, green pea, seaweed
Nutty (roast)	Chestnut, peanut, walnut, Brazil nut
Sulfury	Cooked vegetable, dimethylsulphide (DMS)
Harsh	Acidic, sour, sharp
Toffee	Vanilla
Caramel	Cream soda
Coffee	Espresso
Chocolate	Dark chocolate
Treacle	Treacle toffee
Smoky	Bonfire, wood fire, peaty
Phenolic	Spicy, medicinal, herbal
Fruity	Fruit jam, banana, citrus, fruitcake
Bitter	Quinine
Astringent	Mouth puckering
Other	Cardboard, earthy, damp paper
Linger	Duration/intensity of after taste

of components called the Maillard reaction or nonenzymic browning (see Chapter 3).

It is, of course, possible to heat the germinated grain without drying it. This is called “stewing.” It might happen accidentally in a kiln in which airflow or temperature are too low to carry the load of moisture available and the water condenses in the grain bed or on the inside surface of the kiln (drip-back). Stewing can be easily done in a drum drier where it can be used advantageously to create special malts. Green malt, or rewetted pale malt, can be “stewed” to create colored and flavored malts including crystal malts (those malts with shiny “crystalline” endosperms) because these wet-heating conditions (1) promote mashing within each endosperm and, when the grain is later dried, (2) the Maillard reaction creates intense colors and flavors characteristic of the drying temperature used. Such malts contain no enzymes and depend on the enzymes of the pale malt, blended with them in the mash, for adequate extraction.

Well-modified malt is easy to mill and extract (see Chapter 9) in mashing. Most mashes these days are temperature programmed to produce a series of temperature stands or holds to favor the action of various enzymes,

Relevant Components of a Malt Specification

Brewers have a tendency to pile more and more line items into their specifications for malt, even though some may be mutually conflicting. For example, the best way to get low levels of DMS precursor is to restrict embryo growth and/or use a robust kilning regime. The former may lead to unacceptable undermodification and the latter to excessively high color.

Appropriate line items that should be specified in a malt are,

- (1) Variety
- (2) Modification and homogeneity
- (3) Total protein (T)al soluble (S) protein ratio (S/T)
- (4) Total β -glucan
- (5) Hot-water extract (HWE)
- (6) Filtration performance
- (7) Free amino nitrogen
- (8) Sugar spectrum

- (9) Viscosity
- (10) Color
- (11) Absence of Flocculation factor
- (12) Nitrosamines
- (13) Deoxynivalenol
- (14) S-methyl-methionine (SMM) (lager malt)
- (15) Absence of taints
- (16) Storage time

Typical values as shown in the table:

Parameter	Lager	Ale
Moisture (% max)	4.5	3.5
Friability (%)	> 80	> 85
Homogeneity (%)	> 95	> 95
Viscosity (cP)	< 1.6	< 1.55
β glucan (ppm)	< 200	< 150
Total Protein (% max)	11	10
Soluble Nitrogen Ratio or Kolbach Index	38–44	40–45
Hot water extract (fine grind; % min)	80	82
Fine: Coarse grind difference in Extract (%)	3–4	1–3
Color ($^{\circ}$ EBC)	3–4	5–7
Diastatic Power ($^{\circ}$ ASBC)	> 150	> 100
Nitrosodimethylamine (ppm)	< 0.1	< 0.1
Deoxynivalenol (ppm)	< 0.1	< 0.1
S-methyl Methionine (ppm)	5	< 1

particularly α - and β -amylase; this produces wort of the desired extract yield and correct composition of fermentable and unfermentable sugars. Raising the temperature of the mash to the “mash-off” temperature forces the last of the malt starch into solution to be degraded by the last of the α -amylase present, stabilizes the wort properties and substantially reduces the viscosity of the mash before it enters the lauter.

Though all the wort produced in the mash could flow through the grain bed, which would clarify the wort, this is not strictly necessary; usually wort above the grain bed can be drawn off separately before sparging begins. This should considerably shorten wort separation, with advantages, (1) because lautering is usually the rate-limiting step in brewhouse processes and fast lauter turn-around time is highly valued and (2) brewers seek to minimize extraction of spent grain by minimizing contact of hot sparge water and grain.

Goals for Genetic Modification of Barley

To date, the malting and brewing industries have shown innate resistance to the prospect of using genetically modified raw materials. However, there would be a number of worthy goals for the modification of malting barley if attitudes change:

- (1) Disease resistance
- (2) Improved yield
- (3) Reduced cell wall polysaccharides
- (4) High cell wall polysaccharide degradation potential
- (5) Increased foam potential
- (6) Reduced haze potential
- (7) Dormancy and vigor control
- (8) Modifiability
- (9) Low protein accumulation
- (10) Increased flavor stability potential
- (11) Flavor control

ADJUNCTS

Adjuncts are a significant source of brewers' extract that are not malted materials. They contribute little else but carbohydrate. They are used primarily to make beers less satiating and more crisp, lighter in color and more stable by diluting the contribution of the malt to wort. Adjuncts are primarily grains such as corn (maize) or rice or syrup extracts made from them. Some such as yellow corn grits (YCG) or rice must be boiled in the cereal cooker to gelatinize the starch before it enters the mash; the heat of the boiled adjunct mash is used to bring up the temperature of the main malt mash at a specified rate to the required main mash temperature and fine adjustment is made with steam. Other adjuncts can be added directly to the mash because their treatment, such as rolling or micronizing or extruding, has gelatinized the starch present so that it is ready for amylolysis in the mash. Syrups, made by hydrolysis of starch from cereals especially corn, can be added directly to the brew kettle because they require no further enzyme action; such adjuncts are highly valued because they can be used to raise the gravity of

wort above normal sales gravity and can also raise the level of fermentable sugar in wort above that attainable by the action of malt enzymes alone. Syrups that contain maltose can be used if desirable; this preserves the normal carbohydrate spectrum of wort. This use of syrups in the kettle, allied to the application of amylo-glucosidase during fermentation, permits the production of the immensely popular low calorie/low carbohydrate beers.

Malts and Adjuncts

Product	Details	Purpose/ comments
Pilsner malt	Well-modified malt, gentle kilning regime not rising above ca. 85°C	Mainstream malt for pale lager beers
Vienna malt	Similar to Pilsner malt but higher N, more modification, final kilning temperature ca. 90°C	Mainstream malt for darker lagers
Munich malts	From higher protein barleys (e.g., 1.85% N), prolonged germination, low temperature (e.g., 35°C) onset to kilning to allow stewing (ongoing modification), then rising temperature regime to curing at over 100°C	For darker lager beers
Pale malt	Relatively low N (e.g., < 1.65% N), well-modified, kilning starting at ca. 60°C and rising to a final curing temperature ca. 105°C	Mainstream malt for pale ales
Chit malt	Very short germination time and lightly kilned	Permissible as adjuncts in countries such as Germany with restrictions such as Reinheitsgebot
Green and lightly kilned malts	No or restricted kilning after substantial germination	Alternate to exogenous enzymes
Diastatic malts	High N barley (especially six-row), steeped to high moisture content, long cool germination, gibberellic acid if permitted, very light kilning	High enzyme potential for use in mashing with high levels of adjuncts

Product	Details	Purpose/ comments
Smoked malts	Kilning over peat	For beers with smoky character, e.g., rauchbier
Wheat malts	Germinated wheat, usually somewhat undermodified, lightly kilned (e.g., < 40°C)	For wheat beers
Rye malts		For specialty beers
Oat malts		For specialty beers, including stouts
Sorghum malts	Steeps may incorporate antimicrobials such as caustic; warm germination (25°C)	For sorghum beers; Malted millet may also be used as a richer source of enzymes
Cara Pils (a caramel malt)	The surface moisture is dried off at 50°C before stewing over 40 minutes with the temperature increased to 100°C, followed by curing at 100 to 120°C for less than 1 hour	To afford color and malty and sweet characters to lighter beers
Amber malt	Pale malt is heated in an increasing temperature regime over the range of 49 to 170°C	To afford bread crust, nutty characters to beer and color
Crystal malt	As for Cara Pils, but first curing is at 135°C for less than 2 hours	To afford toffee, caramel characters to beer and color
Chocolate malt	Lager malt is roasted, by taking temperature from 75 to 150°C over 1 hour, before allowing temperature to rise to 220°C	To afford chocolate, roast, coffee, burnt, bitter characters to beer, plus color
Black malt	Similar to chocolate malt, but the roasting is even more intense	To afford harsh, astringent, roast, burnt notes to beer plus color
Roasted barley		To afford sharp, dry, burnt and acidic notes to darker beers. (n.b. drier than roasted malts)
Raw barley		Added in mashing as a cheaper source of extract
Torrefied barley	Barley heated to 220–260°C	Easier to mill than raw barley and starch is pregelatinized
Flaked barley	Grain rolled immediately after torrefaction	Does not need to be milled
Raw wheat		Adjunct for wheat-based beers
Torrefied wheat	Wheat heated to 220–260°C	Easier to mill than raw wheat and starch is pregelatinized; wheat-based adjuncts may be used for barley malt beers to enhance foam
Flaked wheat	Grain rolled immediately after torrefaction	Does not need to be milled

92 Chapter 8

Product	Details	Purpose/ comments
Wheat flour	Fine fraction produced in milling of wheat	Mash tun adjunct not requiring milling
Corn grits	Produced by milling of degermed corn (maize)	Add to cereal cooker for gelatinization; sometimes for economic reasons, or for production of lighter flavored and colored beers
Corn flakes	From torrefaction and rolling of corn	Does not need to be milled or cooked in brew house
Rice grits	Produced by milling of degermed rice	Add to cereal cooker for gelatinization; for production of lighter flavored and lightly colored beers
Rice flakes	From torrefaction and rolling of rice	Does not need to be milled or cooked in brew house
Cane sugar	Refined from sugar cane	Sucrose—for addition to kettle as wort extender or beer as priming agent
Invert sugar	Cane sugar after hydrolysis to fructose and glucose	For addition to kettle as wort extender or beer as priming agent
Corn sugars	Produced from the hydrolysis of corn starch by acid and/or enzymes	Range of products for addition to kettle depending on extent of hydrolysis. At one extreme is high dextrose sugar (approaches 100% glucose) and at the other extreme is high dextrin syrup. Latter for body—very low fermentability. Former for high fermentability (e.g., in production of light beers). Most widely used is high maltose syrup—sugar spectrum reminiscent of that from conventionally mashed malt

Some brewers use non-grist-based sources of color, viz. caramels. This is banned in countries such as Germany under the terms of the Reinheitsgebot, so there they may use coloring beers, e.g., farbier—made from extracts of roast malt that are briefly fermented and charcoal-filtered to remove burnt character. A range of extracts of roasted malts is available in which the color and flavor components have been fractionated and therefore able to be used to introduce color without malt flavors and vice versa.